WAVELET PACKET BASED ON THE TOP-DOWN METHOD

Mi-Sook Chung, Bong-Kyun Rhim, Jae-Ho Choi, and Hoon-Sung Kwak

Dept. of Computer Engineering, Chonbuk National University, Chonju, Chonbuk, 560-756, Korea
TEL: +82-652-70-2411, 2415
E-mail) image@moak.chonbuk.ac.kr
FAX) +82-652-70-2418

ABSTRACT

The wavelet packet based on top-down method is proposed. Previously, Ramchandran and Vetterli have proposed a single tree algorithm, however, it requires of a relatively longer execution time. In comparison to the single tree algorithm, our proposed technique reduces the packet computation time by adopting top-down packet tree architecture in which the variance of the band roles as the decomposition and bit allocation criterion. The bits are allocated to each band by the target bit-rate and variance. Coding is performed for each band within the bit allocation. The simulation results using various still images show that the proposed algorithm requires of a less execution time in comparison to that of the conventional single tree algorithm at the minimal cost of the reduced PSNR. Applications of our proposed method in which time factor is crucial should be useful.

1. INTRODUCTION

A wavelet packet is useful in designing a subband coder(SBC) because it provides flexible subband decomposition to meet a signal's spectral behaviors [1], [2].

The use of an adaptive tree structure using wavelet packets as a generalized wavelet decomposition for signal compression was introduced by Coifman, Meyer, Quake, and Wickerhauser [3]. The idea is based on measures like minimum distortion or minimum number of nonzero coefficients above a certain threshold, etc. None of these is optimal for compression, where the appropriate cost function is rate-distortion(R-D), i.e., a cost function which minimizes the coded rate for a target quality level or equivalently minimized the quantization distortion for a target coding bit rate. Furthermore, the scheme of [3] does not address the important task of optimizing the quantization scheme, which is key to the lossy compression problem. The rate-distortion(R-D) optimized best basis search was done by Ramchandran and Vetterli in [4], where the quantization and best basis choice were jointly optimized in an operational R-D sense, which is summarized below.

- Step 1. Graw a full balanced(STFT-like) tree to some desired fixed depth(i.e., find all the wavelet packet coefficients associated with all bases in the library);
- Step 2. For a fixed λ, populate each node of the full tree with the best Lagrangian cost $D+\lambda R$ over all quantizer choices (i.e., find the best quantizer choice for each node);
- Step 3. Prune the full tree recursively, starting from the leaf node(i.e., find the best basis subtree);
- Step 4. Iterate over λ using a convex-search method to meet the target bitrate(i.e., match the best subtree/quantizer choice to the desired bit budget).

This algorithm [4] requires the long execution time because of iterating step 2 and step 3 over λ to meet the target bitrate. Also, if the different target bitrate is given, the entire algorithm is executed again, though an input signal is same.

Therefore, we propose an new scheme.

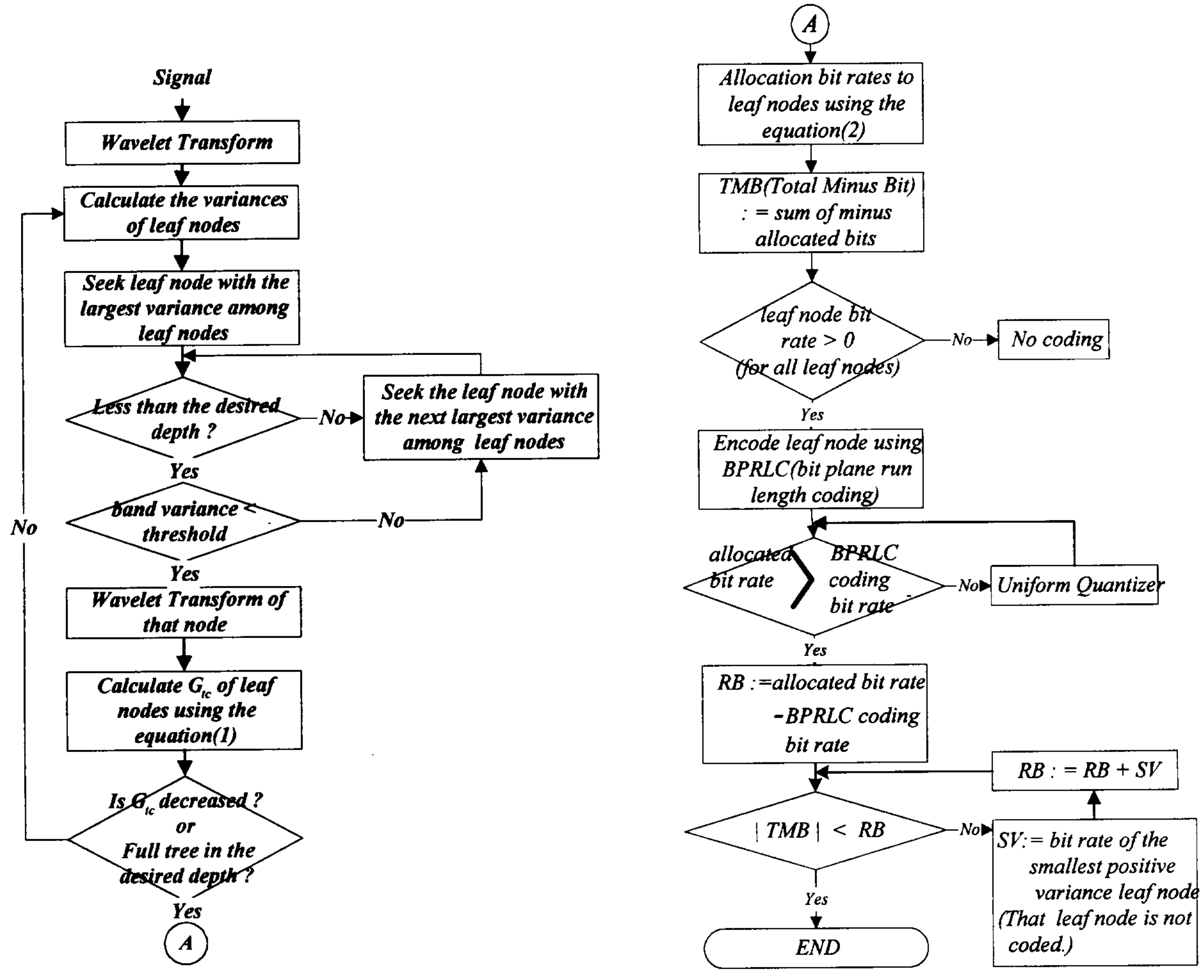


Figure 1. The flowchart of the proposed algorithm

2. WAVELET PACKET BASED ON TOP-DOWN METHOD

An energy compaction measure, namely, the gain of transform coding over pulse code modulation, G_{tc}, has been a common tool for comparing orthonomal transform. This tool is also valid for any orthonormal signal decomposition technique[5]. If the input signal is decomposed into N_1 band, and the p band of the first-level decomposition tree goes through an N_2 band decomposition, G_{tc} is

$$G_{tc}=\frac{\delta_x^2}{\left[\left(\prod_{k_2=0}^{N_2-1}\delta_{pk_2}^2\right)^{1/N_2}\left(\prod_{\substack{k_1=0\\k_1\neq p}}^{N_1-1}\delta_{k_1}^2\right)\right]^{1/N_1}} \quad (1)$$

where δ_x^2 is input signal variance, $\delta_{pk_2}^2$ is N_2 band variances of the second-level decomposition tree, and $\delta_{k_1}^2$ is band variances of the first-level decomposition tree.

The proposed algorithm is given in Figure 1. Using the band variance as a measure, the proposed algorithm is executed on the top-down method. The bits are allocated to each band by the target bitrate and variance of signal band; and within the limit of allocated bitrate each band is coded accordingly.

The corresponding optimum bit allocation equation of leaf nodes is

$$B_{k_1} = B + \frac{1}{2}\log_2 \frac{{\delta_{k_1}}^2}{\left(\prod_{\substack{k_1=0 \\ k_1 \neq p}}^{N_1-1} {\delta_{k_1}}^2\right)^{1/N_1} \left(\prod_{k_2=0}^{N_2-1} {\delta_{pk_2}}^2\right)^{1/N_1 N_2}} \quad \text{for} \quad \begin{matrix} k_1 = 0, 1, \cdots\cdots, (N_1 - 1) \\ k_1 \neq p \end{matrix}$$

$$B_{pk_2} = B + \frac{1}{2}\log_2 \frac{{\delta_{pk_2}}^2}{\left(\prod_{\substack{k_1=0 \\ k_1 \neq p}}^{N_1-1} {\delta_{k_1}}^2\right)^{1/N_1} \left(\prod_{k_2=0}^{N_2-1} {\delta_{pk_2}}^2\right)^{1/N_1 N_2}} \quad \text{for} \quad k_2 = 0, 1, \cdots\cdots, (N_2 - 1) \tag{2}$$

where B is the target bitrate.

3. SIMULATION

The proposed algorithm is tested on SUN 20 with several images of 512x512 size - Lenna and Baboon. Table 1 summerizes the results from the single tree and proposed algorithms.

	single tree algorithm	proposed algorithm
actual bitrate	0.325	0.382
PSNR(dB)	22.731	22.037
execution time	302 sec	127 sec

(a)

	single tree algorithm	proposed algorithm
actual bitrate	0.1596	0.19
PSNR(dB)	28.906	28.543
execution time	257 sec	108 sec

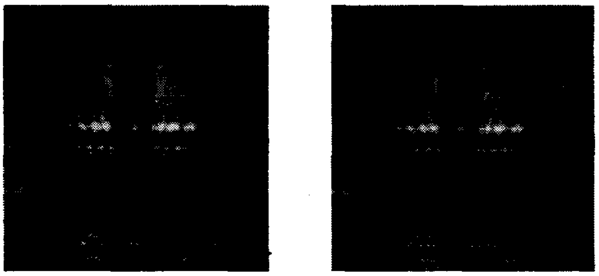
(b)

	single tree algorithm	proposed algorithm
actual bitrate	0.09	0.098
PSNR(dB)	26.085	29.157
execution time	391 sec	157 sec

(c)

Table 1. The tested results(actual bitrate, PSNR and execution time) (a) for Baboon when the target bitrate is 0.4bpp and the desired depth is 3; (b) for Lenna when the target bitrate is 0.2bpp and the desired depth is 3; (c) for Lenna when the target bitrate is 0.1bpp and the desired depth is 4.

The proposed algorithm reduces the execution time in half in most cases in comparison to that of the single tree algotirhm. However, PSNRs in the proposed algorithm are a little decreased than these of the single tree algorithm. Figure 2 shows the reconstuction images.



(a)

(b)

(c)

Figure 2. The reconstruction images for the proposed(left) and single tree algorithm(right) (a) for Baboon when the target bitrate is 0.4bpp and the desired depth is 3; (b) for Lenna when the target bitrate is 0.2bpp and the desired depth is 3; (c) for Lenna when the target bitrate is 0.1bpp and the desired depth is 4.

4. CONCLUSIONS

In the best basis search done by Ramchandran and Vetterli [4], the quantization and best basis choice were jointly optimized in an operational R-D sense. However, the algorithm requires the long execution time because of iterating steps 2 and 3 over λ to meet the target bitrate.

In order to reduce the packet search time, the proposed scheme is executed on the top-down method by using the band variance as a measure.

By eliminating the iteration steps to find the best quantizer and basis subtree, the proposed algorithm could obtain a time reduction gain for search. On the other hand, we need to pay a little cost in the PSNR sense. When the desired depth is 3, PSNR on the proposed algorithm is decreased a little than that of the single tree algorithm. But, to one's surprise, when the desired depth is 4, PSNRs on our proposed algorithm are higher because the small variance bands are not coded on the proposed algorithm.

5. REFERENCES

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